CGI Detector Lifetime and Performance

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Outline

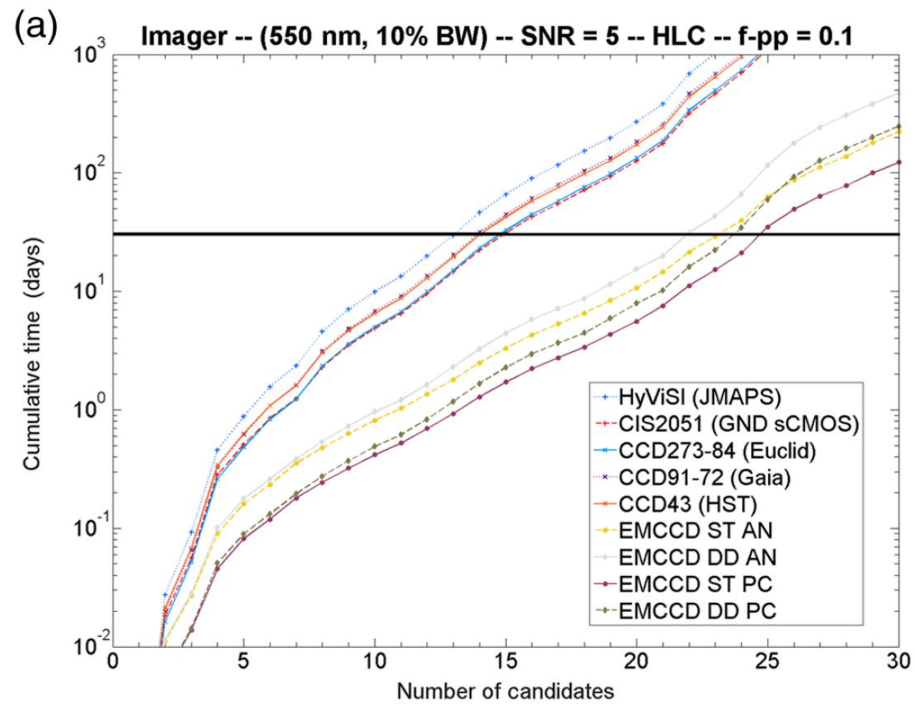
- **Recap of CGI life requirements**
- **Summary of CGI detector performance**
  - Detector noise
  - Detector QE
    - What part degrades over time
- **Back-up charts (from Centre of Electronic Imaging, Open University, London)**

CGI life requirement

- **Finalizing CGI life time requirement with WFIRST project**
  - Converging to 5 year (plus 3 months for in orbit checkout) life time requirement
    - Including electronics parts
    - Including detector
    - Including mechanisms
  - To be finalized by CGI SRR, May 8, 2018
- **Performance evaluation still uses current operations plan ➔ conduct CGI tech demonstration within the first 18 months**
  - More performance reserve if demonstration completed within 18 months
  - Less performance reserve if demonstration at end of 5 years

Detector Selection

- **Noise matters:**
  - Dark noise
  - Read noise
  - Clock induced charge (CIC)
  - ……
- **Detector QE (Impact to signal) matters**
  - Standard QE
  - Photon counting
  - Hot pixels
  - CTE
  - ……
- **CGI team has compared a number of detectors**
- **EMCCD in photon counting mode out performs all others**



"Technology advancement of the CD201-20 EMCCD for the WFIRST coronagraph instrument: sensor characterization and radiation Damage", *Harding, et al*, Journal of Astronomical Telescopes, Instruments, and Systems 2(1), 011007 (Jan–Mar 2016)

dQE: Photon Counting Sensitivity

$$dQE = QE \times [\varepsilon_{PC} * \varepsilon_{CR}] \times [\varepsilon_{HP} * \varepsilon_{CTE}]$$

These factors evolve with radiation exposure – impacting lifetime

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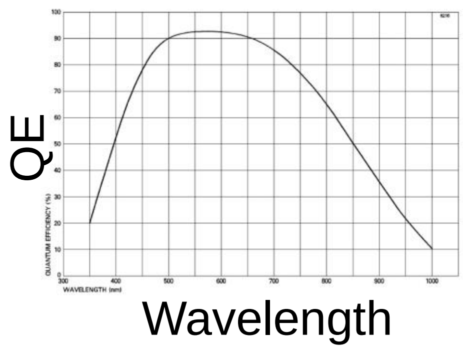

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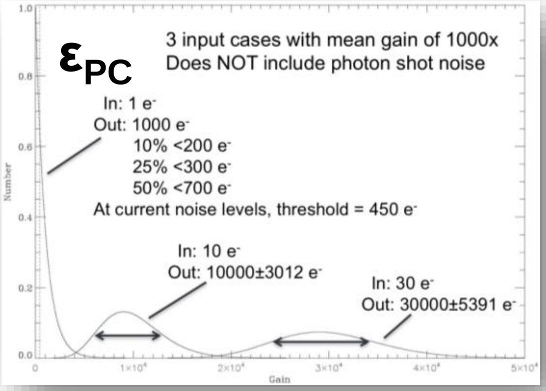

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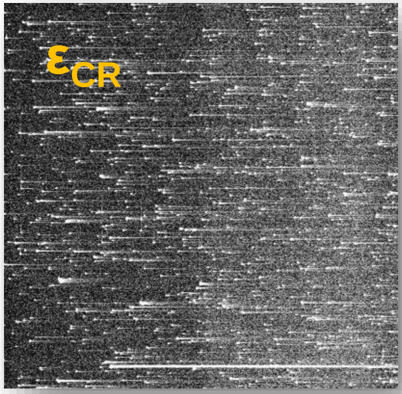

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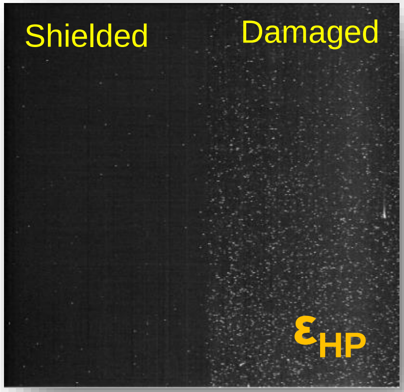

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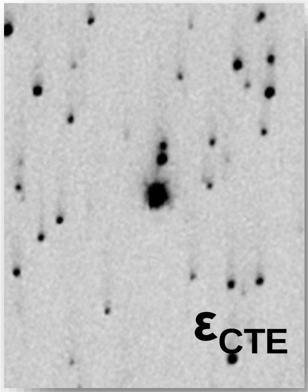

Our program is actively working on optimizing all of these factors to maximize performance.

Data courtesy L. Harding

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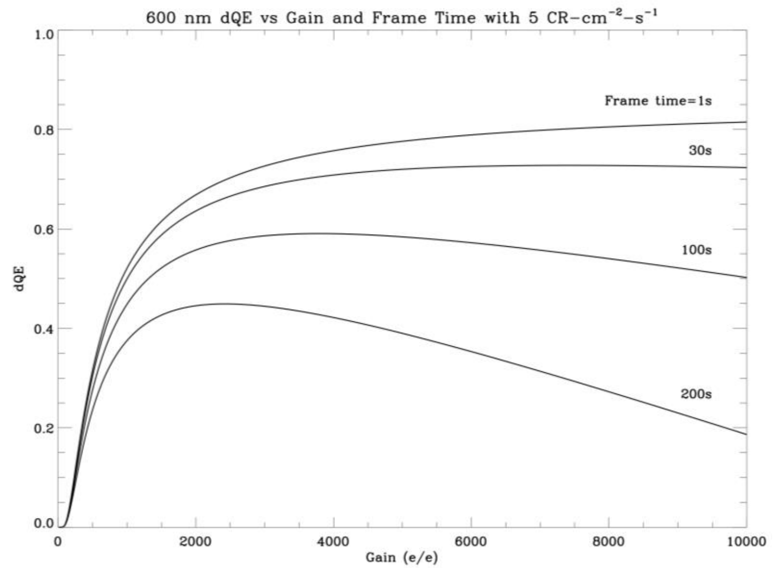
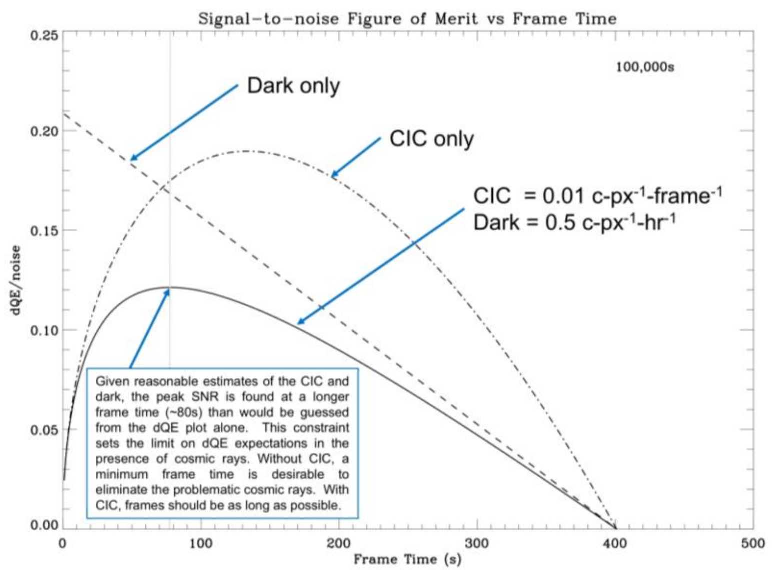
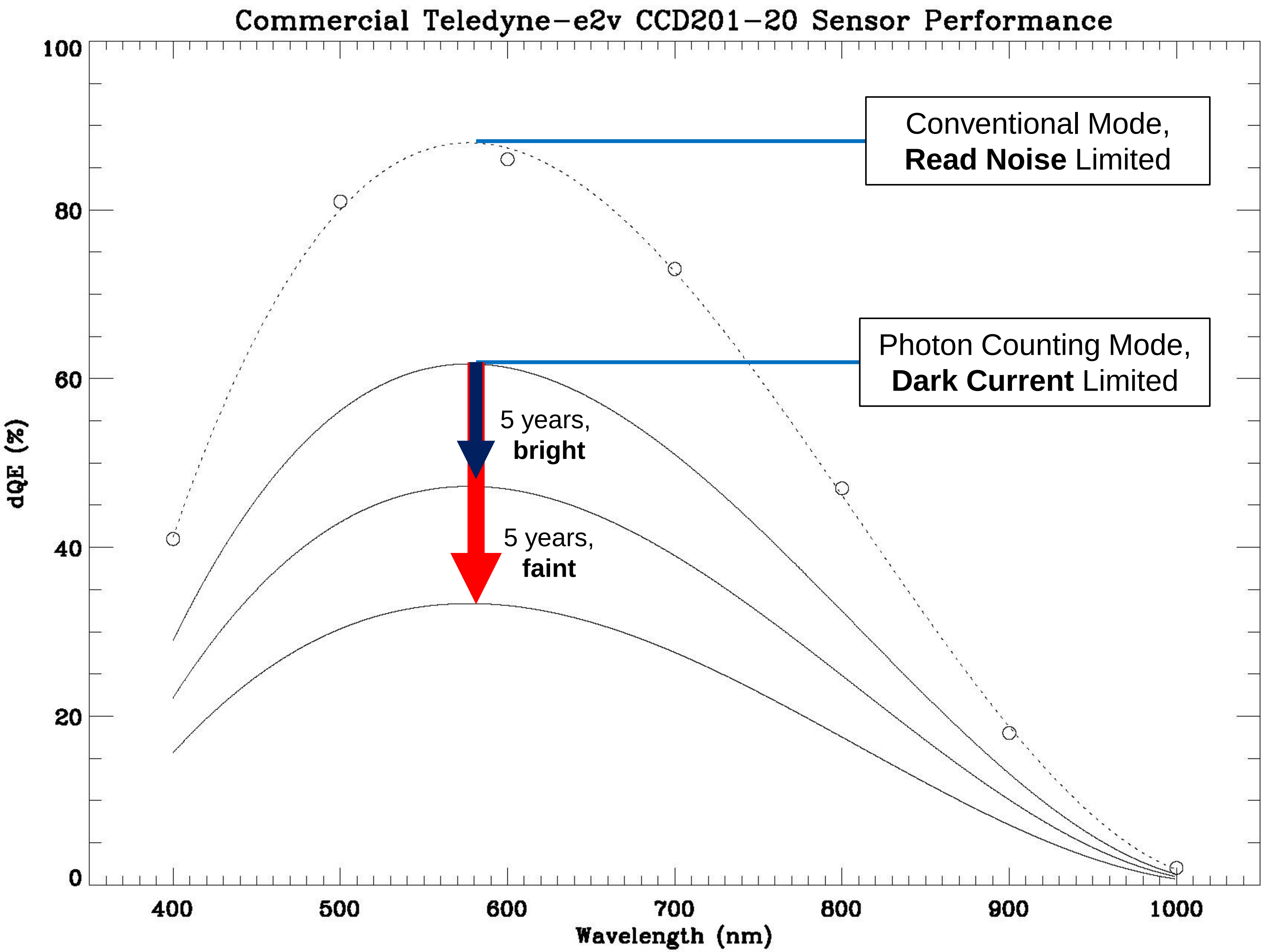
Performance Simulations

- **The dQE terms have functional dependence on gain and frame time that allows us to explore the optimal operating conditions at L2.**
- **The upper right plot shows dQE (beginning of life) as a function of gain.**
  - At low gain, dQE is reduced by photon counting threshold losses
  - At high gain, dQE is increasingly affected by cosmic rays.
- **The lower right plot shows dQE/noise, a proxy for the optimal signal-to-noise condition, as a function of frame time.**
  - Short frame times are dominated by CIC
  - Long frame times are increasingly obscured by cosmic rays
  - The peak signal-to-noise condition *for the commercial sensor* is at a gain of ~4000x and with a frame time of 80s.





Performance vs Lifetime I



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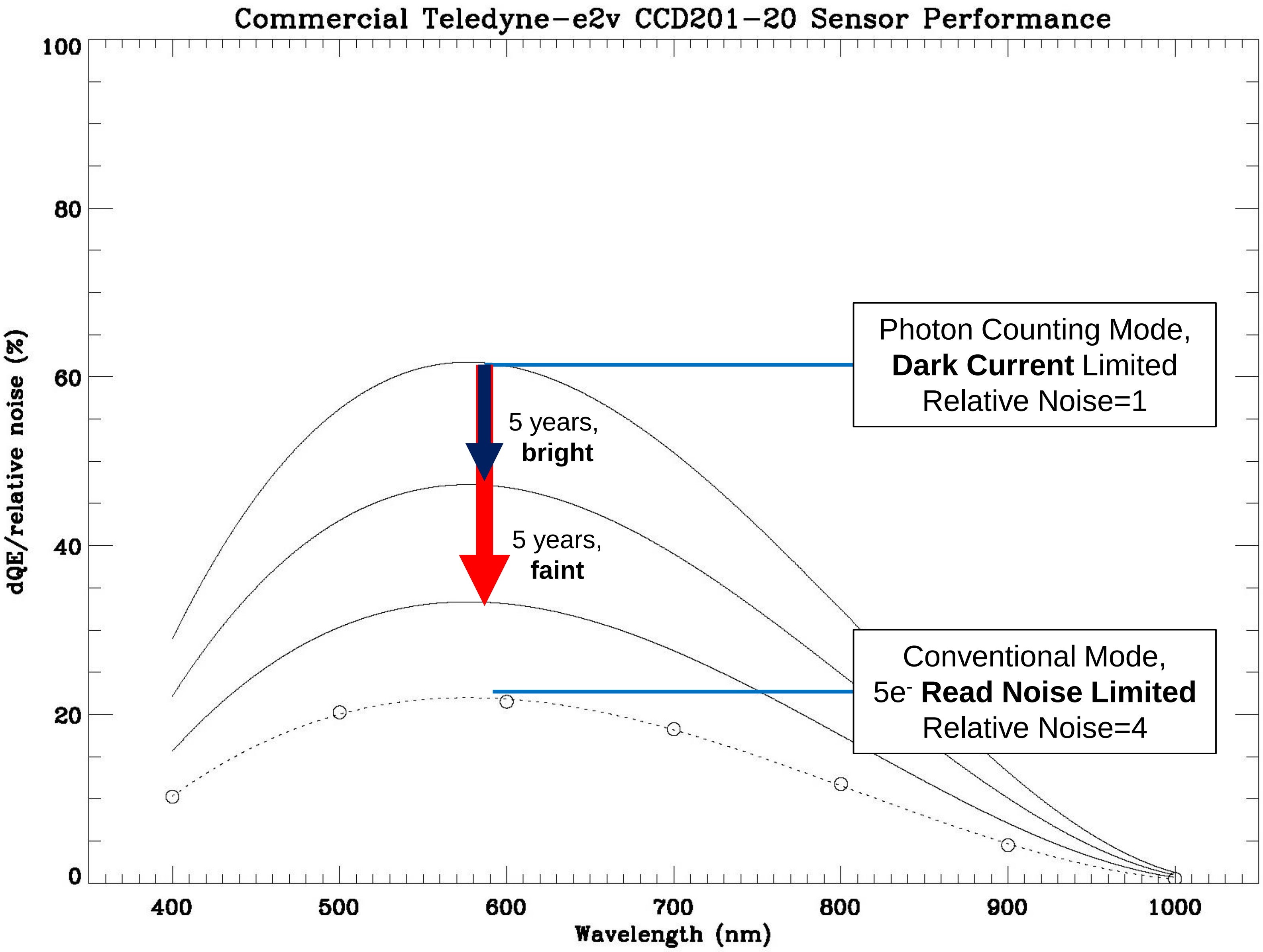
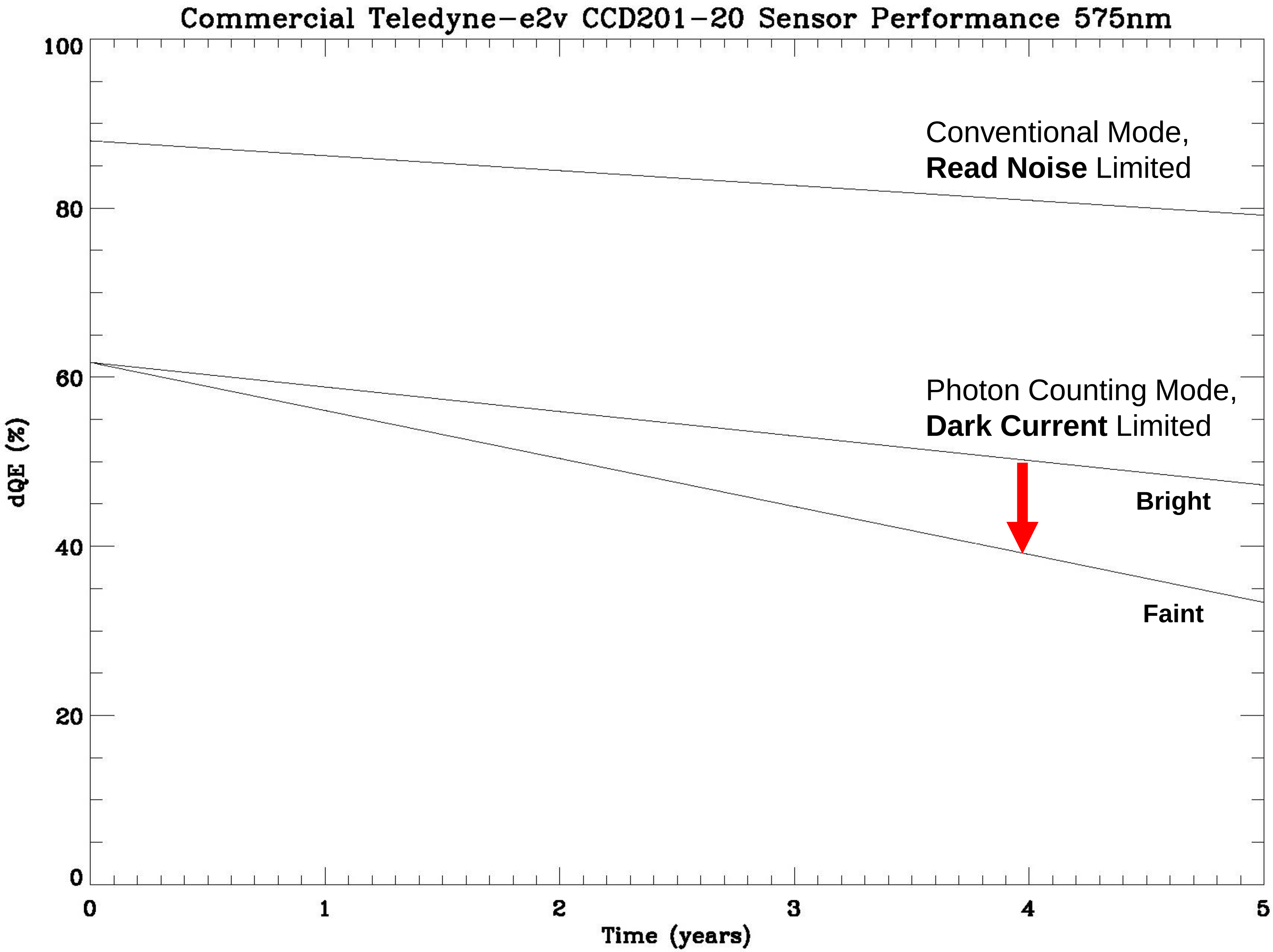
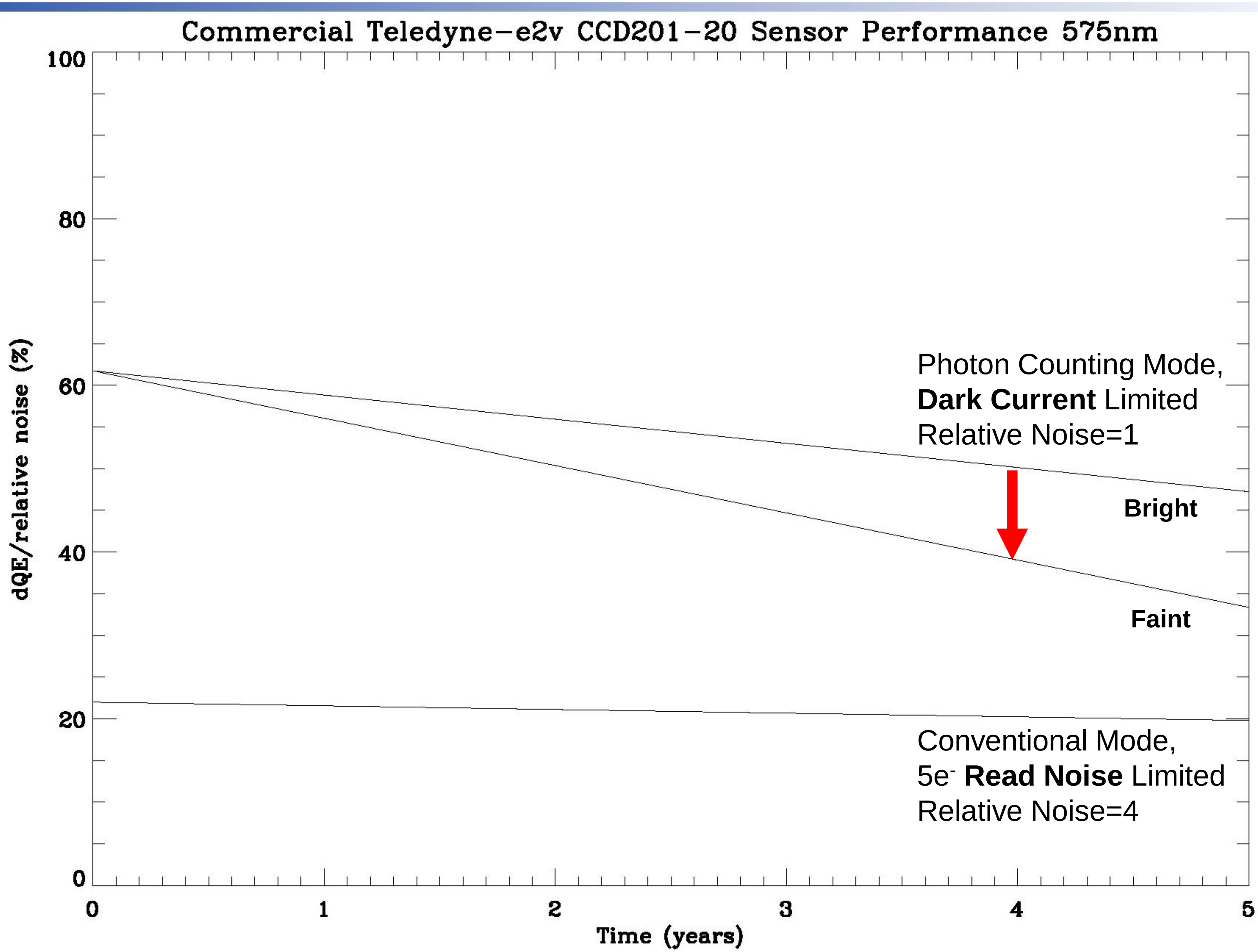


Performance vs Lifetime II



Performance vs Lifetime II



Summary

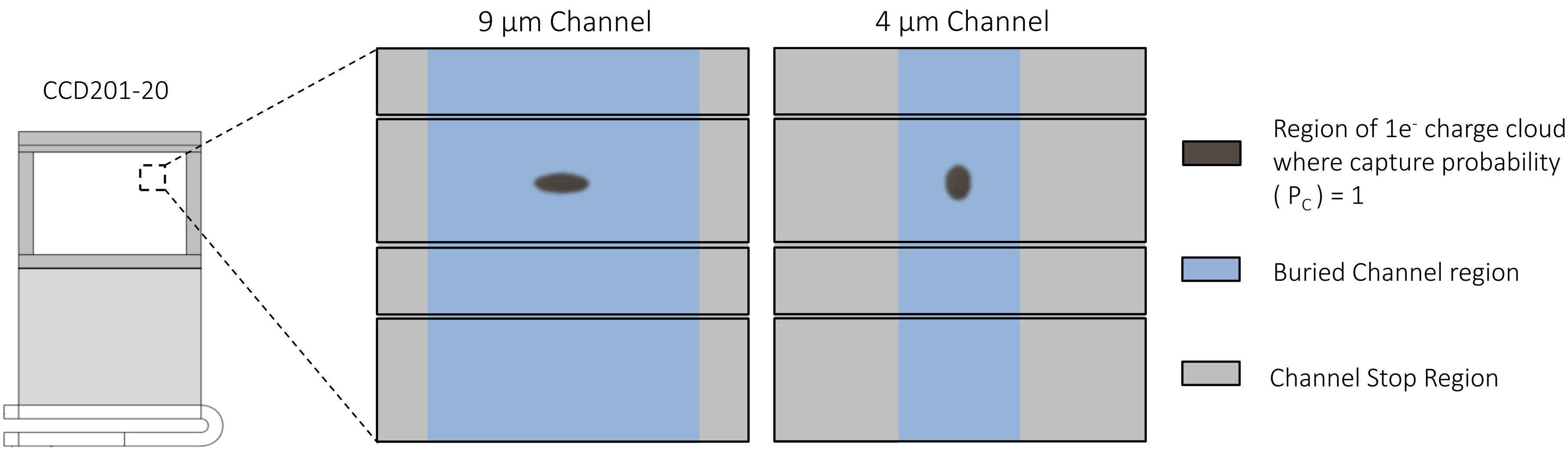
- Working with WFIRST on converging CGI lifetime ~5+1/4 year
- Both EMCCD and CCD have degradations in orbit
- EMCCD still performs better than CCDs when both noise and dQE are considered
- EMCCD development plan includes modifications such as narrow channel to further improve radiation tolerance

Backup chart

CCD201 Narrow Channel Structure

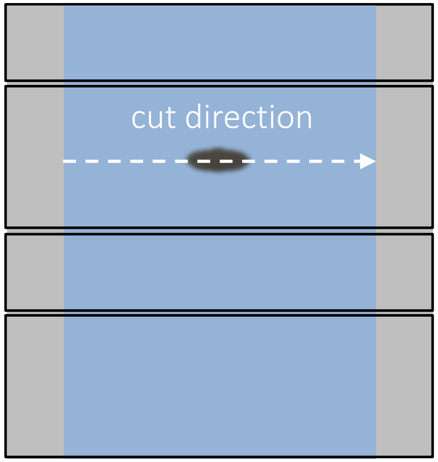
- Narrowing the buried channel redcues the volume occupied by the charge cloud and hence the number of trapping sites encountered by the signal during the transfer path to the output node.
- TCAD modelling of a single electron packet in a CCD201 pixel predicts at least a factor of ×2 reduction in trapping volume (for the example of moving from 9 µm to 4 µm); extending the useable lifetime of the device by an equivalent factor, assuming linear damage with time.

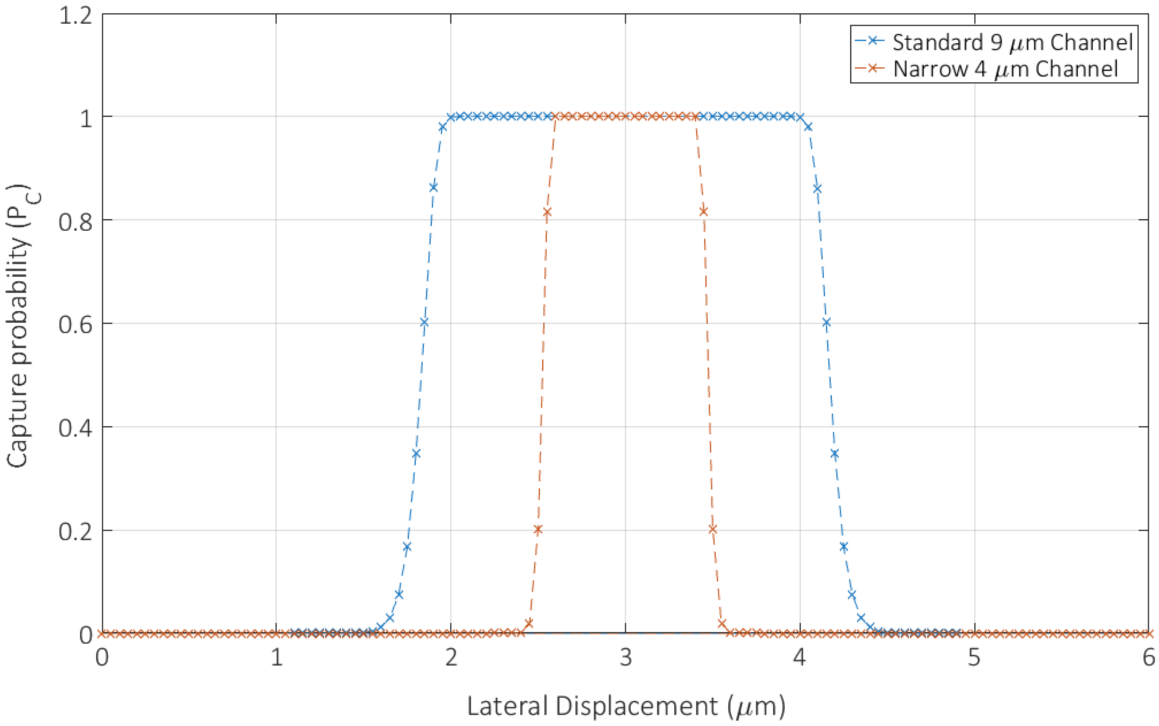
Image Pixel variants



CCD201 Narrow Channel Structure

CCD201 Pixel





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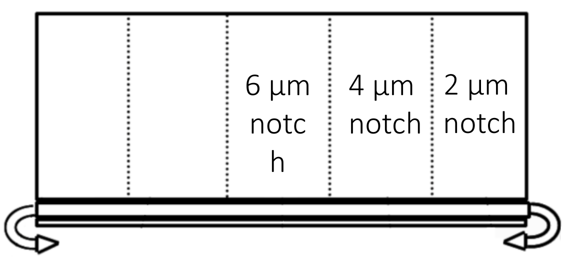
CCD212 Narrow Channel Structure

- A similar test structure to that currently being manufactured by T-e2v has been made before, dubbed the CCD212, and had 6 µm, 4 µm and 2 µm "notch" implants.

- The measured improvement from moving from a 4 µm notch to a 2 µm notch is in good agreement with that predicted by TCAD, adding confidence to the benefits of narrow channel and notch variants of the standard CCD201.

CCD212 Structure[1]



Notch Design	TCAD predicted factor improvement (moving from 4 µm to 2 µm)	Fe^{55} CTI factor improvement[1] (moving from 4 µm to 2 µm)
4 µm	1.44	1.39
2 µm		

[1]source: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/6690/66900K/Laboratory-and-radiation-performance-testing-results-for-the-e2v-model/10.1117/12.733974.short?SSO=1